## List of Fascicles issued to 22nd June, 1929 (*continued*) :—

### Part IV. Coleoptera.

| | *Date Issued.* |
|---|---|
| Fasc. 1. Carabidæ. By H. E. Andrewes. 9 text-figures. Dytiscidæ. By A. Zimmermann. 2 text-figures. Staphylinidæ. By M. Cameron, M.B. 2 text-figures. Hydrophilidæ. By A. d'Orchymont. 1 text-figure Clavicornia and Lamellicornia. By G. J. Arrow. 13 text-figures. Pp. 1–66. 1927, 4to. 3*s.* | *19th December*, 1927. |
| Fasc. 2. Heteromera, Bostrychoidea, Malacodermata and Buprestidæ. By K. G. Blair, B.Sc. 14 text-figures. Elateridæ. By R. H. van Zwaluwenberg. 10 text-figures. Melasidæ (Eucnemidæ). By E. Fleutiaux. Cerambycidæ. By Chr. Aurivillius. 1 plate. Brenthidæ. By R. Kleine. 4 text-figures. Anthribidæ. By Karl Jordan, Ph.D. 11 text-figures. Proterhinidæ. By R. C. L. Perkins, D.Sc., F.R.S. Pp. 67–174. 1928, 4to. 5*s.* | *25th February*, 1928. |
| Fasc. 3. Throscidæ. By K. G. Blair, B.Sc. 1 text-figure. Chrysomelidæ. By S. Maulik, M.A. 18 text-figures. Pp. 175–215. 1929, 4to. 2*s.* 6*d.* | *23rd February*, 1929. |
| Fasc. 4. Platypodidae and Scolytidae. By C. F. C. Beeson, D.Sc. 13 text-figures. Pp. 217–248. 1929, 4to. 2*s.* 6*d.* | *22nd June*, 1929. |

### Part V. Hymenoptera.

| | |
|---|---|
| Fasc. 1. Apoidea, Sphecoidea, and Vespoidea. By R. C. L. Perkins, D.Sc., F.R.S., and L. Evelyn Cheesman, F.E.S., F.Z.S. 12 text-figures. Larridæ. By Francis X. Williams. 12 text-figures. Formicidæ. By Dr. F Santschi. 9 text-figures. Pp. 1–58. 1928, 4to. 5*s.* | *25th February*, 1928. |

### Part VI. Diptera.

| | |
|---|---|
| Fasc. 1. Streblidæ and Nycteribiidæ. By L. Falcoz. 7 text-figures. Hippoboscidæ. By G. F. Ferris. 6 text-figures. Pp. 1–21. 1927, 4to. 2*s.* 6*d.* | *23rd July*, 1927. |
| Fasc. 2. Nematocera. By F. W. Edwards, M.A. 20 text-figures. Cecidomyiinæ. By H. F. Barnes, B.A., Ph.D. 4 text-figures. Pp. 23–108. 1928, 4to. 5*s.* | *23rd June*, 1928. |
| Fasc. 3. Stratiomyiidæ, Tabanidæ and Asilidæ. By Gertrude Ricardo. 6 text-figures. Larvæ of Stratiomyiidæ. By P. A. Buxton, M.A. 2 text-figures. Dolichopodidæ. By C. G. Lamb, Sc.D. 8 text-figures. Sarcophagidæ. By P. A. Buxton, M.A. 9 text-figures. Muscidæ. By J. R. Malloch. Pp. 109-175. 1929, 4to. 5*s.* | *11th May*, 1929. |

### Part VII. Other Orders of Insects.

| | |
|---|---|
| Fasc. 1. Isoptera : Family Termitidæ. By Gerald F. Hill. 14 text-figures and 1 plate. Odonata. By Lt.-Col. F. C. Fraser, I.M.S., F.E.S. 5 text-figures. Pp. 1–44. 1927, 4to. 2*s.* 6*d.* | *28th May*, 1927. |
| Fasc. 2. Plectoptera. By R. J. Tillyard, Sc.D. (Cantab.), F.R.S., and J. A. Lestage. 2 text-figures. Siphonaptera. By P. A. Buxton, M.A. Thysanoptera. By Richard S. Bagnall, F.R.S.E., F.L.S. 6 text-figures. Pp. 45-76. 1928, 4to. 2*s.* 6*d.* | *23rd June*, 1928. |
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### Part VIII. Terrestrial Arthropoda other than Insects.

| | |
|---|---|
| Fasc. 1. Isopoda Terrestria. By Harold G. Jackson, D.Sc. 2 plates. Scorpionoidea. By P. A. Buxton, M.A. Pseudo-scorpiones. By A. Kästner. 11 text-figures. Acarina. By Stanley Hirst. 2 text-figures. Pp. 1–27. 1927, 4to. 2*s.* 6*d.* | *23rd July*, 1927. |
| Fasc. 2. Myriopoden (Myriopoda). By C. Attems. 4 text-figures. Araignées (Araneida). By Dr. Lucien Berland. 79 text-figures. Pp. 29-78. 1929, 4to. 2*s.* 6*d.* | *22nd June*, 1929. |

Department of Entomology
Keeper's Study.
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BRITISH MUSEUM (NATURAL HISTORY)

# INSECTS OF SAMOA

## AND OTHER SAMOAN TERRESTRIAL ARTHROPODA

## PART IX.

FASC. 1. Pp. 1–32

## DESCRIPTION OF THE ENVIRONMENT

By P. A. BUXTON, M.R.C.S.,
LONDON SCHOOL OF HYGIENE AND TROPICAL MEDICINE

WITH TWO TEXT-FIGURES AND SIX PLATES



B. M.
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# INSECTS OF SAMOA
## AND OTHER SAMOAN TERRESTRIAL ARTHROPODA

Although a monograph, or series of papers, dealing comprehensively with the land arthropod fauna of any group of islands in the South Pacific may be expected to yield valuable results, in connection with distribution, modification due to isolation, and other problems, no such work is at present in existence. In order in some measure to remedy this deficiency, and in view of benefits directly accruing to the National Collections, the Trustees of the British Museum have undertaken the publication of this account of the Insects and other Terrestrial Arthropoda collected in the Samoan Islands, in 1924-1925, by Messrs. P. A. Buxton and G. H. E. Hopkins, during the Expedition of the London School of Hygiene and Tropical Medicine to the South Pacific. Advantage has been taken of the opportunity thus afforded, to make the studies as complete as possible by including in them all Samoan material of the groups concerned in both the British Museum (Natural History) and (by courtesy of the authorities of that institution) the Bishop Museum, Honolulu.

It is not intended that contributors to the text shall be confined to the Museum Staff or to any one nation, but, so far as possible, the assistance of the leading authorities on all groups to be dealt with has been obtained,

The work is divided into nine "Parts" (see p. 3 of wrapper), which are subdivided into "Fascicles." Each of the latter, which appear as ready in any order, consists of one or more contributions. On the completion of the systematic portion of the work it is intended to issue (in Part IX), a general survey, summarising the whole and drawing from it such conclusions as may be warranted.

A list of Fascicles already issued will be found on pp. 3 and 4 of this wrapper.

E. E. AUSTEN,
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# INSECTS OF SAMOA

## PART IX, FASC. 1

## DESCRIPTION OF THE ENVIRONMENT

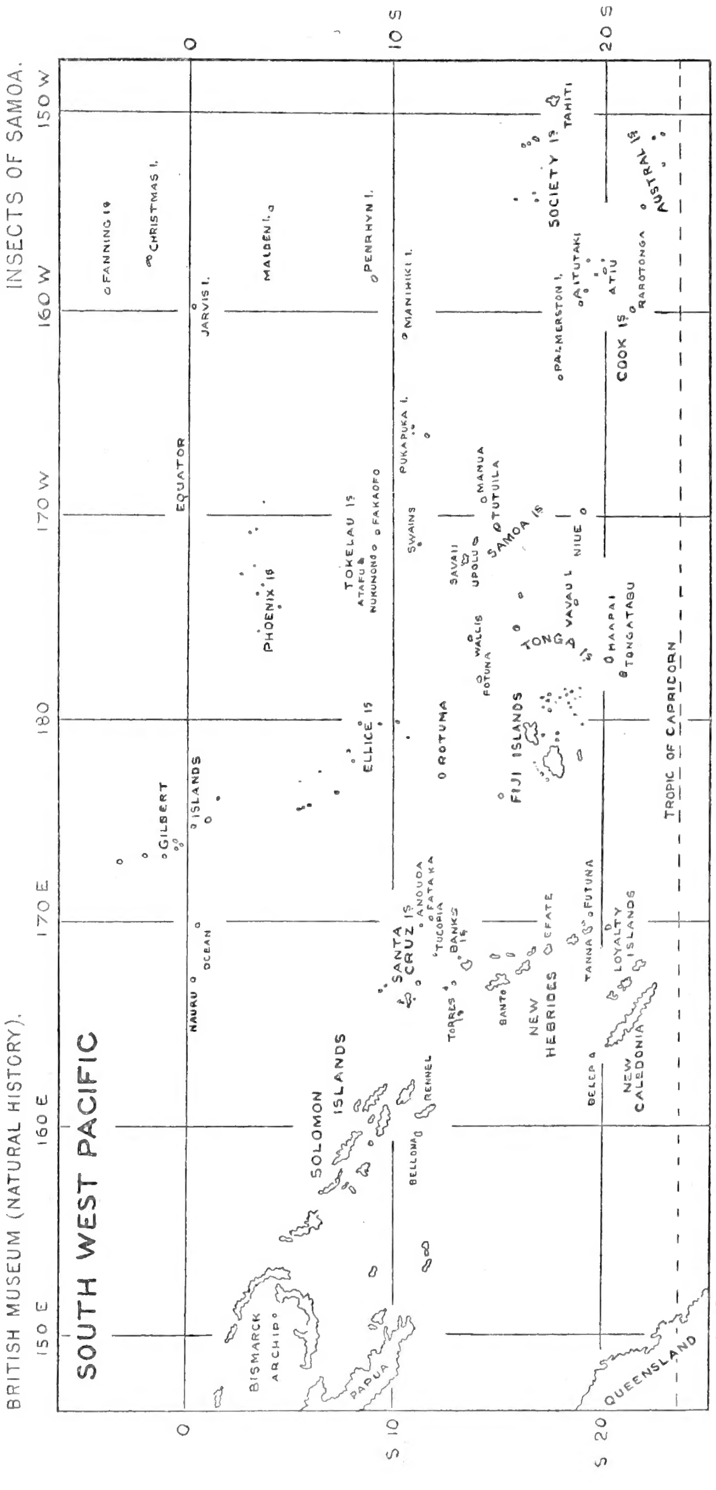
BY P. A. BUXTON, M.R.C.S.

## THE ISLANDS.

### GEOGRAPHY.

BEFORE we proceed to describe the position and structure of Samoa, it would be well to observe its general relation to other archipelagoes. So far as its tropical boundaries are concerned, Oceania may be said to lie to the east of New Guinea (see map, Text-figure 1). It is generally divided into Melanesia and Polynesia, and this arrangement is convenient for our purpose * though the basis is ethnographical. The principal archipelagoes in Melanesia are the Bismarcks, the Solomons, the Santa Cruz Group, the New Hebrides and New Caledonia. To the east lies the great archipelago of Fiji, which is generally regarded as a part of Melanesia, though in many respects it is a boundary region with some Polynesian characteristics. East of Fiji lies Polynesia, the principal island groups being Samoa, Tonga, the Cook Islands, the Society Islands and the Marquesas; all of these groups contain high volcanic islands. There are also the following groups, all of them low atolls: the Ellice, the Phoenix, the Tokelau, the Paumotu Islands and many others. There are also two important archipelagoes which are ethnographically Polynesian, but so different in fauna as to be excluded from Polynesia for our purposes; the Hawaiian Islands, lying on the Tropic of Cancer, far removed from other Oceanic Islands, and possessing a remarkable fauna; and New Zealand, entirely extra-tropical, and therefore

* No reference is made to the Caroline, Ladrone, Marshall, Gilbert Islands, etc., generally grouped as "Micronesia"; it seems that the fauna is not closely related to that of Samoa.




TEXT-FIG. 1.—Map of the South-West Pacific Ocean.

unlike the rest of Polynesia, even if it had not its own very ancient and peculiar fauna.

Samoa lies well within the tropics at a great distance from any large mass of land (Text-figure 1); the position of the islands accounts to a great extent for their climate (page 10) and their fauna (page 19). As the islands are about 14° S., they lie in the southern equatorial current, a surface stream which crosses the Pacific in these latitudes from east to west. This body of water is very wide, extending from a few degrees north of the equator down to lat. 20° or even 25° S. It flows throughout the year and gives off a number of currents, which pass away in a southerly direction. The relation of this current to the distribution of terrestrial life is apparent. The isolation of Samoa, which is a Polynesian word for the archipelago and not for any one island, is very much greater than first appears; it should be remembered that the ten-degree squares on the map have sides of approximately 600 miles, so that Samoa is about 130 miles from the north of Tonga, and 500 miles from Fiji. Moreover, the islands themselves are small compared with the immense ocean; the area of Savaii is only 730 square miles, and this is more than half of the total area of the archipelago. If one compares Samoa with two better-known Hawaiian Islands, Savaii is almost the same size as Maui, and only a sixth of the size of the island of Hawaii. What is true of Samoa is true of Pacific Islands in general; one must never forget the vastness of the ocean, and the great expanses of sea which separate islands and archipelagoes from one another. According to Daly (1916), there are 73,000 square miles of land, and 35,000,000 square miles of water in Oceania, so that the proportion of land to water is as one to five hundred; and yet Brigham's " Index " gives the names of 2,600 islands.

## Geology.

In this vast area, geological and especially petrographic surveys have been few, but one definite conclusion seems to be established, and it bears directly on these studies on the fauna of Samoa. A line drawn from New Zealand and the Kermadecs, through Tonga and Fiji, to the New Hebrides and the Solomon Islands will mark an important geological boundary. In the islands which I have named, and in islands to the west of this line, some evidence exists of former continental areas. There is detailed petrographic evidence in support of this view, and in nearly all the islands mentioned there is great and recent elevation. Here, then, is the probable edge of a continent, and east of it lies the

"great Pacific basin." East of the line there is no petrographic evidence * of continentality, and the ocean is continuously deep. All the islands are either volcanic, as Samoa, or atolls of coral limestone, as Rose island and the Ellice group. From islands of either type it is very difficult to obtain evidence of the previous geological history of the area, unless indeed one accepts the Darwin-Dana hypothesis that atolls are evidence of subsidence. But even if that hypothesis is in the main true, and modern opinion tends to favour it (Davis), it can hardly stand by itself as sole evidence for the previous existence of a great land mass.

The geological history of the Pacific has been recently discussed by Gregory. Few would disagree with his conclusions that the ocean has been smaller than it is now : the previous existence of land masses both in the north and the south is almost a matter of general consent. But our problem is the centre. Gregory holds that "lands survived across the Central Pacific apparently until the Lower Kainozoic." With the geological evidence I am not competent to deal, but one must remember that strata and fossils are absent, so that it is hardly surprising that there is a difference of opinion in geological circles. One should also remember that even an elevation of 10,000 feet, which would unite all Melanesia to New Guinea, and New Zealand, Fiji, Tonga and Norfolk Island to Queensland, would leave Samoa surrounded by sea. But even if we admit a land mass in the centre of the Pacific in Lower Kainozoic times, we must suppose that it sank completely, for it seems incontestable that the present fauna of Samoa is truly oceanic, and that neither the islands nor their flora are a remnant of a great land. I think that this conclusion will be admitted when the insect fauna is discussed at a later date ; the other elements of the fauna (page 19) support this view.

I have discussed the geological evidence with some hesitation, realising its importance as a basis for faunistic work. The most valuable general papers are those by Marshall, Gregory, and Daly (1916) ; a full recent discussion of atolls and coral reefs has been published by Davis ; Thomson has written on the geology of Western Samoa, and Daly (1924) on American Samoa. The papers mentioned contain lists of references, and make it unnecessary for further papers to be quoted here. One would be glad to see fuller geological surveys

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* But see Daly, 1924 : the question is raised whether the occurrence of quartz-bearing trachyte in Tutuila, Samoa, should not be taken as evidence of "continentality."

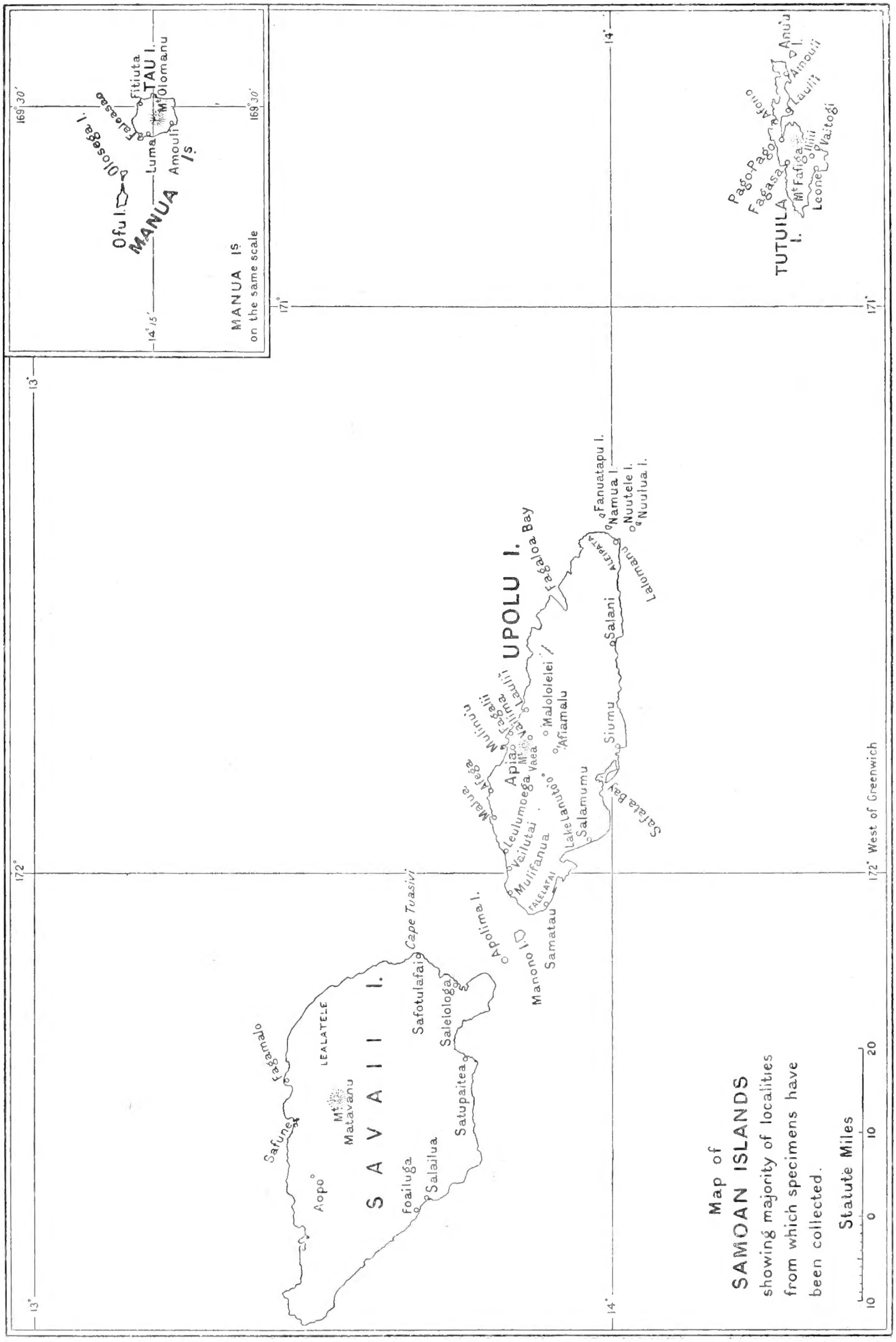
made in many parts of Oceania; it is also most desirable that a competent person should review the evidence, with particular reference to Wegener's hypothesis, and to modern views on geodesy.

With regard to Samoa itself, no elevated coral limestone exists; the islands consist of volcanic rocks, principally olivine basalts according to Thomson. Daly (1924) holds that Tutuila is the oldest of the Samoan islands; it has no active volcano, and no crater lakes; the oldest lavas in Tutuila "are no younger than an early stage of the Pleistocene period, and may be Pliocene, if not older." The Manua islands, to judge from their degree of dissection, are more recent than Tutuila. Savaii, with active volcanos, is thought to be the most recent island in Samoa; Upolu, with crater lakes but no active volcanos, is intermediate in age between Savaii and Tutuila.

## Topography.

I now propose to give a description of the structure of Upolu, the island most familiar to me and most fully explored and described by other travellers. The reader must understand that though Upolu is only about twice the size of the Isle of Man, much of the interior is unmapped, and indeed absolutely unknown to white men (and almost equally unknown to the present generation of Samoans). The island is elongate, some 45 miles long and 8 to 12 miles wide; the area is 430 square miles. In the part of the island south of Apia there is a clearly distinguishable main ridge, nearly flat and a couple of miles wide. Its altitude is 2,000 to 2,200 feet. Malololelei is a farmstead in a clearing, a little below the ridge on the north side; it is used as a rest-house, and is an admirable centre for collecting. From it the island falls steeply to within a few hundred feet of sea-level on the north and south sides. Below this level the slope is much less steep, and the ground is cultivable. Along the ridge there is a chain of many old craters running from a little north of west to a little south of east. Some of these craters are filled with water, and are typical "crater lakes." Lanutoo is the only one which is easily reached: it lies on the rather flat ridge of the island, above which the rim of the crater rises steeply perhaps 100 feet. The water-level is perhaps 100 feet below the crater rim, and the lake circular and a quarter of a mile in diameter. East of Lanutoo there is a considerable area of "red clay" (no doubt a rotted tuff) on the main ridge of the island. I do not know of any other area of this material on Upolu. Many of the craters are dry and incomplete, as most of the perimeter has disappeared, leaving a steep crescentic

BRITISH MUSEUM (NATURAL HISTORY). INSECTS OF SAMOA.




TEXT-FIG. 2.—Map of Samoa, indicating places where collections were made.

ridge, narrow on the top; Tanua, Vaitoa and Le Pue are examples of this type. Few of these craters rise much beyond 2,000 feet; one, which I have not visited, reaches 3,600 feet, the highest point in Upolu. The higher parts of Upolu are almost unknown except in the neighbourhood of Malololelei; it is probable that a rich endemic fauna remains undiscovered.

In the hills the rainfall (page 16) is very heavy; on the north side of the ridge of Upolu it is about 200 inches, and one presumes that on the south side it is higher still, owing to the S.E. Trade Wind. Much of this water is carried off by a series of gorges which lie roughly parallel to one another, and run northwards and southwards. The water descends by a series of waterfalls and rapids, till it reaches the lower and less steep parts of the island (Plates 1, 2, and 3). The gorges in which these streams run are deeply cut, and the sides are very steep and in many places unclimbable. These gorges are very numerous, so that the intervening ridges are narrow; some of them are mere knife-edges. It is therefore almost impossible to traverse the island from east to west, except round the coast or along the main ridge. If one set out to go from east to west crossing the gorges and the intervening ridges, I very much doubt if one could travel four miles in a day.

If one starts on the ridge of the island and follows any small stream downhill, one finds that the banks are a few feet high; but where it leaves the broad ridge and commences its steep descent, it passes very suddenly into one of these gorges with high precipitous sides. I believe that many of them are old lava tunnels, of which the roof has collapsed, and that this explains the abrupt transition from banks a few feet high to precipitous walls. This is clearly true of one stream about half a mile west of Malololelei. This stream drops suddenly, like so many others, into a steep-sided gulley, in which it runs for several hundred yards; it then enters a lava tunnel without altering the direction of its course. The tunnel is circular, about 20 feet in diameter, and flat bottomed (Plate 4, B). It is fairly straight, and has one short branch. It runs steeply downhill for perhaps 200 yards, with the stream on its floor, or beneath its floor. At this point the roof has caved in for 30 yards: apparently this happened quite recently, for the edges of the cavity are steep. After this short break the tunnel continues downhill, but one can only follow it 30 or 40 yards as it is filled with blocks of stone. It is clear that this stream flows in a lava-tunnel, which is in course of becoming a steep-sided open gorge. Numerous other lava tunnels are known in various parts of Samoa (Thomson).

As these mountain torrents reach the lower, less steep parts of the island, they unite with one another, but the total volume of water becomes visibly less and less: it appears that the greater part of the drainage from the hills is carried away by subterranean channels. This water again reaches the surface near high-tide mark in a series of springs, which are found on most parts of the coast. There is hardly a village without its spring and bathing pool.

The lower slopes of the hills are much less steep than the upper, and they pass gradually, in many parts of Upolu, into a zone of nearly flat ground close to the coast. Some of these areas are small delta plains in the mouths of rivers.

Between Apia and Mulifanua this zone of cultivable ground is so wide and so nearly flat that one might take it for an ash plain, or even for the floor of an old coral reef lagoon. It is neither. It is a plain of lava which has rotted into black soil full of boulders of lava in some places, but in others the lava persists as ribs running down from the central part of the island. Close to the sea it is rather flat and uniform, owing to inblown coral sand; farther back it is much rougher. It cannot be ploughed anywhere by reason of ridges of lava and basaltic boulders. There is no evidence of elevation in the shape of elevated coral or old shore benches.

It is on this relatively flat ground close to the sea that practically every village is placed. Here also one finds the cultivation, the introduced plants and weeds and many of the introduced insects. (Plate 4, C.)

The actual beach, wherever one occurs, is white, and consists of fragments of coral and shells pounded up so that it appears to be sand. (Plate 4, A.) The beach runs down to a lagoon full of coral, with occasional patches of the same "sand" in which the plant *Halophila* grows; it is there that the submarine midge *Pontomyia* (vi, 64)* may be taken at appropriate seasons. The lagoon is separated from the ocean by the fringing reef, which shelters most of the shore of Upolu. In places, however, there is no lagoon, for the black cliffs of basalt form an "iron-bound" coast, and fall straight into deep water without any fringing reef. These basalt cliffs are the ends of ancient lava-flows, which came from the interior of the island, filled the lagoon, covered the reef and plunged into deep water. They are even more characteristic of Savaii than of Upolu.

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* References to other "Parts" of the present work are quoted in this form, the words "Part" and "page" being omitted.

The other Samoan islands may be dealt with more shortly. SAVAII, the largest island in the group, is about 47 miles long, with a greatest width of 27 miles. It contains by far the highest mountains in Samoa, the summit being about 6,000 feet above sea-level. The higher parts of Savaii are almost unknown, the summit having been reached only twice so far as is known. Mr. E. H. Bryan of the Bishop Museum, Honolulu, collected for several days up to 5,000 feet; no other insect collector has worked in the higher mountains of Savaii. Savaii contains an active crater, and there are very large areas of rough lava erupted at various periods, including several which are of known age; even the flow of about the year 1760 is only covered with a poor type of low forest, consisting of very few species of trees, and among the trees the surface of the lava is still exposed, bare of humus.

Thomson has already described APOLIMA, of which the area is about 2 square miles. It is a tuff crater, open on the north, the bottom of the crater a little above sea-level. The outer slope is very steep, in many places a precipice, bare of vegetable life. The inner slope is less steep and covered with forest.

I have been on Apolima, and also on NUU TELE, the structure of which has not been described so far as I know. Like Apolima, it is a breached tuff crater. It is larger than Apolima, but very similar to it. The bottom of the crater is flat, and has been cultivated, and there is at least one perennial stream. From the bottom the sides rise very steeply, but they can be climbed in many places. The crescentic top of the island is very narrow, in many places less than 10 feet wide. I estimated it to be 400 feet above sea-level. The outer side of the island is precipitous. There is a coral reef across the mouth of the little harbour, where the tuff cone is breached. Round the outside of the island there is no fringing reef, and the reefs shown between this island and Nuulua, on Admiralty Charts and other maps, are non-existent. I have looked down on continuous deep blue water in this direction from the top of Nuu Tele.

There are a number of smaller islands lying close to Upolu. The largest, and the only one inhabited by man, is MANONO, which lies off the N.W. coast of Upolu; it is within the fringing reef which encircles that part of Upolu, and can hardly be expected to be of interest faunistically.

The islands so far described form "Western Samoa," and are a Mandatory Territory administered by New Zealand. The remaining islands form "American Samoa." The distinction is not only political, for the sea between Upolu and

Tutuila is nearly 6,000 feet deep. One is, therefore, prepared for considerable differences between the faunas of the two parts of the archipelago.

Tutuila has an area of only 54 square miles, but it has a disproportionately long and irregular coastline. The geology has been discussed fully by Daly (1924); the U.S. naval chart of this island is much more complete and accurate than any existing map of Savaii or Upolu.

I have never visited the Manua Group, and know no general account of the islands; the total area of the group, which includes several islands, is only 18 square miles.

Rose Island, or Rose Atoll, which is included in Samoa on general geographical grounds, is an uninhabited atoll, 140 miles east of the Manua group. It has been well described by Mayor. To the biologist, it has no connection with the other Samoan islands, for even among atolls it is unusually barren.

## THE CLIMATE.

Many years ago the German Government opened a meteorological Observatory on a peninsula close to Apia. Its work was not interrupted by the war, and its records furnish valuable information about nearly all the climatic factors which are studied by meteorologists. It is the most important centre of meteorological work in the tropical Pacific.

The naturalist may well regard Upolu as a type of tropical island, lying far from disturbing continents. He would like to build on the good foundation laid by the meteorologists, and make a profound study of the climate, considered as a part of the environment in which the plants and animals live. This work would require many years, for when the meteorologist has studied the temperature in a ventilated white screen, the biologist wants to know what differences exist between the forest and the shore, or the rat's hole and the bird's nest: in the white screen he finds no living thing, unless it be an earwig. Again, the meteorologist's mean rainfall is a sound, if conventional, foundation, but the botanist knows that the trees on the two sides of a hill receive different amounts of rain, and at different seasons, and that the canopies of the trees distribute the rain differentially among the undergrowth. In the past we biologists have relied too much upon the meteorologist; we have forgotten that he is studying the dynamics of the atmosphere, and if his facts do not meet our needs, then we must collect our own. To him the most important instrument is the barometer,

which is no more use to us than an astrolabe ; and it is because we have followed his lead too closely that we still lack any adequate conception of the climate of a tropical island as it affects the fauna and flora. I shall therefore use the meteorological foundation and build up as far as I can a general picture of the climate of Samoa as the biologist sees it. I shall feel at liberty to generalize, inasmuch as tables, facts, and graphs have been published elsewhere.*

## Solar Radiation.

Let us first study Solar Radiation, though it is difficult and our knowledge is incomplete: we put it first because the many types of radiation which we receive from the sun, and the differences in their seasonal distribution, are the most important part of the climate so far as the plants and animals are concerned. These seasonal differences depend on changes in the relative position of the sun and Samoa. The archipelago lies within the tropical zone, between 13° and 14° S., and because of this situation, the sun is vertically overhead at noon twice in the year, in October and again in February. Between these dates, in the "summer" of the southern hemisphere, the sun reaches its most southerly position on 21st December, and on that date its zenith angle at Apia is 9° 40′. After passing the vertical in February, the sun goes northwards, and on 21st June it reaches its maximum northerly declination, with a zenith angle of 37° 12′. In speaking thus, I have used the convention of a fixed earth and a moving sun. Insolation should therefore be more intense, because the sun is more nearly vertical, from about October to about March, and less so during the other half of the year. Moreover, this seasonal difference would be exaggerated by difference in the length of the day, for the 21st of December is very nearly 13 hours long, and the shortest day (20th June) is about $11\frac{1}{4}$ hours. Furthermore the earth is nearer the sun during the southern summer than during the other part of the year. For these three reasons, more radiant heat would be received by Samoa between October and March, provided the sky were clear, than at other times of year. But as a matter of fact the period from October to March is more cloudy than the rest of the year ; during these months the number of clear days per month is generally below 20, and sometimes below 10. In the other months, or at any rate from June to September, there are 20–25 clear days (a " clear " day is one with at least seven hours of recorded sunshine). Apart from the presence of

* Buxton and Hopkins, 1927, pages 14 to 50. See also Angenheister.

actual cloud, the increased amount of water vapour makes the atmosphere less penetrable to radiant heat from October to March.

One finds, then, that considerable seasonal differences are to be expected in the radiation received on Samoa, and that the situation is complicated by a number of factors. If one endeavours to make actual measurements of radiation received, one must select a particular part of the solar spectrum for study ; it is probably easiest to consider first the radiant heat, and its seasonal distribution.

During our stay in Samoa, we took a series of readings with black-bulbed maximum thermometers, both naked and *in vacuo*. It is clearly understood that the readings obtained with these instruments are not capable of exact physical interpretation ; but they have a certain value for purposes of comparison. Moreover, we are biologists, not physicists, and we are studying plants and animals which are exposed to a variety of conditions ; they are heated by the sun's rays, and cooled by convection currents, and we can understand a little of their state by reading a naked black-bulbed thermometer at different seasons of the year. The facts we collected revealed a season of less intense heat radiation in the months from about May to July, and a season of greatest mean intensity about December.

There is one objection to the use of maximum thermometers with black bulbs, whether these are exposed, or *in vacuo*, for the day's reading is recorded at that instant when insolation is most intense, other factors being equal ; but the plant, or the soil, or the insect receives radiation throughout the day, and it is the sum total which one would wish to study. In fact one wants the mean temperature of some object exposed to wind, radiation, etc., and so large that its temperature does not vary rapidly. The island itself appeared to be an appropriate object, and the soil temperature was taken daily at two depths, beneath the surface of bare earth. But the results were disappointing, because the soil is so porous that the rain sinks rapidly through it, and disturbs the temperature, at any rate as low as 16 inches below the surface.

For one reason or another none of these methods of studying radiant heat are adequate, especially when one remembers its great biological significance. The only appropriate instruments seemed to be the pyrheliometers, all of which are expensive and somewhat difficult to use. They are suited to the physicist and the observatory, but one does not feel that they meet the needs of biology, for we wish to study the radiant heat received at a large number of different stations, and if we cannot have large numbers of absolute

instruments, we must be content with comparative readings, taken at different seasons, altitudes, aspects and places. For this purpose I devised and used an instrument, which has been discussed and described elsewhere (Buxton, 1926). Briefly, it consisted of a blackened bulb, *in vacuo*, filled with absolute alcohol. This part of the instrument was exposed to the sun, the heat of which volatilized some of the alcohol. The alcohol vapour passed by diffusion into a burette, at shade temperature, in which it condensed and was measured once a day. With this instrument we demonstrated :—

1. That the total amount of radiant heat received varied with the seasons, in accordance with expectation ; in the spring and autumn, when the sun was most nearly vertical, the monthly totals were between 9 and 12 per cent. of the annual total ; in midwinter (May, June and July) the monthly totals were between 4·4 and 6·6 per cent. of the annual total.

2. That at the season when the sun was more nearly vertical, an hour of sunshine produced about twice as much distillate as it did at the season when the sun was farthest from the vertical.

It is probable that my instrument, or some improvement on it, has considerable value to biologists, provided that it is remembered that it is not a physical standard, and that it cannot be used in places in which there are great seasonal differences in shade temperature. So far as Apia is concerned, our work has been extended by Thomson's measurements, taken with the Gorczynski pyrheliometer. In publishing his results he has not been concerned with the reception of radiant heat by the island of Upolu, but with the transmission of radiation through different thicknesses of damp tropical atmosphere. Much of his paper is therefore physical and outside our scope. But he publishes a table showing the amount of radiation received during bright weather, at different seasons, and under various conditions prevailing before and after noon. This represents a material increase in our knowledge of the seasonal and hourly distribution of radiation at sea-level in the damp tropics.

## Duration of Sunlight.

Radiant heat is only one of the many types of solar radiation which are of importance to plants and animals. A number of facts are known relating to the duration of daylight, and of bright sunlight, as recorded by a Campbell Stokes instrument at Apia. The longest day (21st December) is 12 hours 57 minutes ; the shortest (20th June) is 11 hours 19 minutes, but the prevalence

of rain and cloud in the "summer" makes the distribution of bright sunshine quite different. In fact August, though the days are relatively short, has the highest mean record for sunshine (200 hours), and the lowest mean (133 hours) occurs in February, in spite of the fact that the days are then relatively long. Putting the same facts in another way, about 40 per cent. of the daylight is recorded as sunshine in December, January and February; from May to October the figure is about 50 per cent. or higher, and it reaches 60 per cent. for the month of August. Bearing this in mind, and remembering also that an hour of sunshine in the southern summer will distil twice as much alcohol in my instrument as an hour in winter, one begins to appreciate how complex the whole subject is.

And beyond this we must remember that there exist whole realms which are important, but unexplored; for instance, the seasonal distribution of particular parts of the visible spectrum (for not all sunlight is equally valuable to the green plant), and of that part of the ultra-violet which reaches the surface of the earth; and the spatial distribution of solar radiation on the north and south sides of the island, on hill and valley, on leaf and soil.

## Temperature.

Leaving the important but obscure subject of radiation, what knowledge have we about the more commonplace elements of the Samoan climate?

The annual mean temperature of Apia is 25·78° C. (78·40° F.); the mean of the coldest month, July, is 25·01° C. (77·02° F.), that of the hottest 26·28° C. (79·30° F.). The difference between the mean temperatures of the hottest and coldest months ("mean annual range") is therefore only 1·27° C. (2·28° F.). The mean daily range (the difference between the mean monthly maximum and minimum) is only about 6·4° C. (11·52° F.). The extreme range of temperature recorded over a space of thirty years is only from 16·4° C. (61·52° F.) to 34·6° C. (94·28° F.). One may sum it up by saying that there is very little difference in temperature between day and night and between season and season: this is true whether one considers means, or maxima and minima. Indeed, one can hardly think that the seasonal differences in temperature are of any biological significance.

The temperatures which are quoted above were recorded at the Observatory, which is at sea-level, but at the tip of a peninsula; its climate is therefore even more oceanic than that of the rest of Upolu. We made a comparison between the temperature at the Observatory and that at the Hospital, which is 145 feet above sea-level and about two miles from the Observatory, though only about one

mile from the sea. Readings taken over a period of nineteen months showed that the Hospital had consistently higher maxima and lower minima. The difference between mean maximum (or minimum) at Hospital and Observatory was only about 2° C.; this appears trivial, but probably has an appreciable effect upon human beings, who are living close to the limits of the tolerable. The Hospital is therefore a little more "continental" (if we may apply that term to the Samoan microcosm) than the peninsula on which the Observatory stands. The centre of the island has doubtless a still greater daily range of temperature; Angenheister states that at Afiamalu, at the centre of the main ridge of Upolu, at an altitude of nearly 2,000 feet, the mean daily range for the year is 9·6° C. (17·3° F.); that is to say, that it is half as much again as it is at the Observatory. Apart from differences in temperature between the parts of the island, one wants to know what is the effect of the forest canopy, or of a roof, upon the area beneath it. At the Hospital our thermograph was exposed in a standard screen, which stood in the open, thirty yards from any large building. A hundred yards away was a residence, well built, and appropriate to the tropics, with wide verandahs on all sides and a double roof. In this house we selected a draughty place between two doors which were always open, and exposed a second thermograph. This instrument showed that the construction of the house was adequate to keep the temperature down during the day, for the maximum in the house and the screen were nearly the same; but at night the roof of the house prevented cooling, in spite of the free ventilation, and the minimum in the house was nearly 2° C. above that outside. The effect of a canopy of forest is similar. We made a direct comparison between the garden at Malololelei, which was open to the sky and freely exposed to wind, and a position in the edge of the forest, only about a hundred yards away. In a period of seventeen days the mean daily range in the garden was 8·0° C., in the forest 4·0° C. Had we set up instruments farther into the forest it is probable that we should have recorded still more equable conditions. Furthermore, the figures quoted above were taken from thermometers in a ventilated box, fixed in a tree, but insects and other creatures live in masses of epiphytes, or among dead leaves, or in other situations in which the mean daily range is probably even less than 4° C. It is right to add that there are a few situations in which the mean daily range of temperature is greater than it is in a standard screen. The monthly mean grass minimum temperature at the Hospital was nearly two degrees Centigrade below the screen minimum, during the nineteen months in which records were kept. Considering that this

figure was obtained on bare soil beneath open sky, it is remarkable that the difference was not greater. But in any case areas of grass or other low vegetation are few in Samoa, and the grass minimum does not represent an environment frequented by many animals.

It would be fair to summarize our knowledge of temperature in Samoa by saying that it is extremely equable and that the differences between day and night, month and month, or one place and another, are very slight.

## Rainfall.

The mean annual rainfall of Apia is 2,738 mm. (107·8 inches); in a period of sixteen years, the highest and lowest annual totals have been 4,387 mm. (172·7 inches), and 1,747 mm. (68·8 inches). There is a very regular distribution of rain through the months, with a single wet season, from November to February, during which 51 per cent. of the total rain falls. The period from May to August is much drier, and receives only 16 per cent. of the annual total. The wettest month is January, with a mean fall of 419 mm. (16·5 inches); the driest month is July, with a mean fall of 71 mm. (2·8 inches). But though the seasons are so clearly defined and though the driest month receives only a sixth of the rainfall of the wettest month, it would be misleading to speak of a dry season. How could one say that July is dry in Apia, when nearly three inches of rain falls, which is more than the mean rainfall of London for any month of the year? If the separate monthly totals for sixteen years are considered, one notices that in that period the monthly rainfall was less than an inch on only eight occasions; it was above two inches on more than nine-tenths of all the months. The highest record for any one month in the sixteen years was just over one metre. Taking the figures for "rainy days"* for the same period, the lowest number in one month was three; and in 80 per cent. of the months there were more than ten rainy days. It is evident that this very heavy precipitation must have great biological importance; it drowns some creatures, prevents the flight of others, and carries large quantities of soil and debris into the sea. It is also well known that heavy falls of rain are common in Samoa; for instance, during nineteen months at the Apia Hospital our highest daily record was 190·9 mm. (7·52 inches), on 1st May; records of several inches a day are almost commonplace. It would be of great interest to the biologist

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* A rainy day is one on which more than 0·25 mm. (0·01 inch) of rain is measured.

if the facts accumulated at the Observatory could be tabulated so as to show the mean number of days for each month in which the rainfall exceeded one inch, two inches, etc.

With regard to the local distribution of the rain in different parts of Samoa, little of any value is known. The mean rainfall at the Observatory is 2,738 mm. (107·8 inches), but this is taken at sea-level and on the lee side of Upolu, and should be regarded as the figure for the driest part of the island; even at the Hospital, which is only a couple of miles away, and 145 feet above the sea, the fall is about 16 per cent. higher. According to Angenheister, the annual precipitation is probably about 5,000 mm. (say 200 inches) at an altitude of 600–700 metres in the hills in Upolu; this is approximately true at Malololelei, the centre round which so much collecting has been done; in the higher mountains in Savaii it is perhaps 7,000 mm. (say 280 inches). At Pago Pago, Tutuila, the mean annual precipitation for the years 1900 to 1920 was 4,981 mm. (196·1 inches). The highest and lowest annual totals were 7,224 mm. (284·4 inches) and 3,305 mm. (129·9 inches). The rainfall of Pago Pago is very high considering its situation at sea-level, but is probably due to the precipitous hills which surround the harbour on all sides. The distribution of the rain through the year is much as it is in Apia; the driest month, August, has a mean fall of 201 mm. (7·9 inches), the wettest, February, 615 mm. (24·2 inches). It is evident that the annual and monthly rainfall of many other stations in Samoa should be studied and recorded, but though so much more remains to be done, we can be positive that the local differences in rainfall are very slight, compared with differences in New Caledonia, or the islands of Hawaiia.

To express the matter in brief, rain is abundant at all seasons, and in every part of Samoa; there is a clear seasonal difference in distribution, but no dry season; by any ordinary standard, deficiency of rain is unknown, and excess is only too common.

## Humidity.

As the temperature is nearly constant, as rain is abundant and well distributed, and as the islands are surrounded by the ocean, it follows that the atmosphere is moist at all times and seasons. The means of each of the twelve months lie between 80 and 86 per cent., but these figures are based only on readings taken at 7, 14 and 21 hours; had night readings been included the mean values would have been even higher. It is probable that the slight seasonal

changes in humidity have no biological significance. Monthly means for relative humidity will be found elsewhere (Buxton and Hopkins, page 40).

## Wind.

Enough has been said to show that the climate of Samoa is warm and damp, at all times and seasons. The perspiring entomologist soon learns to recognise that his comfort depends entirely on the wind, for the warm damp air does not cool him unless it is in motion. From data derived from a recording anemograph at the Observatory, it appears that there is a seasonal difference in the velocity of the wind, which is consistently higher from May to October, and lower in the other months. This period, in which the mean velocity of the winds is greater, is also the season of the regular Trade Winds from the south-east; for though the direction of the prevailing winds at all times of the year has an easterly component, this is increased at that season. The winds and the surface currents of the ocean therefore approach Samoa from the same direction (page 3). There is a curious apparent anomaly here; though the fauna comes from the west, the prevalent wind and current are from the east or south-east. In spite of this, one cannot assume that the wind has had nothing to do with the arrival of the insects in Samoa, for the Trades and other easterly winds are a shallow stream, and at a level of roughly two or three miles above the sea there is a steady anti-Trade wind, blowing from the west or north at all seasons. These currents in the upper air are more rapid, and they have also a greater vertical depth than those which blow at the surface of the earth, and it is possible that they have been important carriers of insects, etc., from Asia into Oceania. It is known that these anti-Trade currents have a low humidity, but whether this has any biological importance is not certain.

The increased comfort which one feels during the season of the Trade Winds can best be measured by the katathermometer. I shall not quote the figures obtained with this instrument (which are given in the work by myself and Hopkins, page 45), for it measures the loss of heat from a body maintained near the temperature of a warm-blooded animal, so that its readings cannot relate to the life of cold-blooded insects. But there can be no doubt that seasonal changes in the velocity of the wind, in an atmosphere which is almost constantly hot and damp, must produce seasons of more or less evaporation. These changes may well be of considerable biological import, for they affect the leaves and animals, and also the soil itself, but they have not yet been studied.

One cannot leave the subject of wind without referring to hurricanes. According to Visher and Hodge, who have recently summarized what is known from Australia, and the tropical Pacific, hurricanes are recorded from Samoa about two or three times a year; but it is to be understood that few of these are very violent or destructive. Hurricanes are commoner in Fiji and the New Hebrides, and the seas to the west, than they are in Samoa. East of Samoa they are rarer still, so that our archipelago may be said to be on the edge of the area which is disturbed by these events. In Samoa, and the islands near it, hurricanes have a sharply defined season; one-third occur in January, and three-quarters in the first three months of the year. From May to November they are extremely rare. They come to Samoa from the north or the east; from what is known about tracks of hurricanes generally, one may assume that they are curving down from the Equator, so that it is not probable that they will bring many living plants or animals to the Samoan Islands. The thickly forested hills afford shelter from wind, and one cannot suppose that hurricanes do serious damage to the insects of Samoa, where they appear to have very little biological importance.

## THE FAUNA AND FLORA.

### Fauna.

Before we proceed to study the insects and to draw such conclusions as may be possible from the systematic parts of this work, it would be well to review present knowledge of certain other components of the fauna of Samoa, and of other archipelagos. In writing this summary I have received much help from the staff of the British Museum.

The only Samoan Mammals apart from Cetacea are a small rat (*Rattus exulans*) and three sorts of bat (two species of fruit bat, *Pteropus*, and a small insectivorous bat, *Emballonura semicaudata*). The small rat has evidently been carried about in canoes during the voyages of the Melanesians and Polynesians; it is found under different names in nearly all parts of Oceania, southwards to New Zealand, eastwards to Tahiti, and northwards to the Hawaiian Islands (Thomas). Its relatives, *Rattus concolor*, etc., are widely distributed in the Malay Peninsula and Malay Islands (Miller). With the exception of this rat, and of various bats, no native mammals exist in any part of Polynesia, or anywhere in Melanesia except the more westerly Solomon Islands and the Bismarck

Archipelago. The dugong (*Halicore*), found in the shallower seas which surround the Malay Islands, New Guinea and Melanesia, does not extend its range so far east as Samoa. Feral pigs, escaped from villages, have existed since before the days of European penetration; there are wild cattle, which owe their introduction to Europeans, in the forests of Upolu.

The Birds deserve rather full discussion, because they are the only extensive group of animals of which the distribution in the Malay Islands and Oceania has been satisfactorily studied, so that they have already contributed largely to our general knowledge of the zoogeography of these regions.

The number of land birds known to inhabit Samoa is only about 34; the figure is not absolutely certain as some old records are obscure owing to questions of synonymy, but one may say with some confidence that no unknown species remain to be discovered. It is clear that they are very much better represented in the Samoan fauna than are the mammals. About fourteen of these species are peculiar to Samoa, and others are only known as occurring in Fiji or Tonga, and Samoa. But though the proportion of endemic species is so high, there are few which are confined to one or two of the islands of Samoa. The birds which seem to be endemic to a part only of Samoa are the following: a species of White Eye (*Zosterops samoensis*) is only known from Savaii, which is the eastern limit of the distribution of this genus in Oceania; it is curious, but apparently true, that the genus has extended east from Melanesia through Fiji to Savaii, and been defeated by the sea separating Savaii from Upolu, a matter of about nine miles with two intermediate islands. *Lalage sharpei* and *Pinarolestes powelli* are perhaps confined to certain islands in the archipelago, but our knowledge of them is very limited. The most interesting group in respect of island endemicity is the kingfishers; *Todirhamphus recurvirostris* is endemic to Upolu, and perhaps Savaii, and apparently absent from Tutuila; outside Western Samoa the genus is only known from some of the Society Group, and from one island in the Paumotus. The kingfisher of Tutuila is a species of *Halcyon*, a genus of wide distribution absent from Upolu and Savaii; the species in Tutuila is probably endemic. Even in the genus *Ptilinopus* (Fruit Doves) there is no species or subspecies peculiar to one island in Samoa; this is remarkable, for *Ptilinopus* has been prodigal of endemic species in many archipelagos, and also in some single islands. The Tooth-billed Pigeon (*Didunculus strigirostris*) is the most remarkable bird in Samoa. The genus is endemic and monotypic, and a family has been created for its reception, though it is doubtful if its peculiarities

warrant this treatment. At one period it excited great interest owing to the facts that it occurred in a remote island, and bore a superficial resemblance to the Dodo, but it is now held that its anatomical peculiarities are not really very great. But if the family Didunculidae is allowed to stand, it is apparently the only endemic family in the land fauna of Samoa, which is characterized by possessing a great number of endemic species and even genera, but practically no endemic groups of higher status.

There are certain birds which are distributed eastwards as far as Fiji, but absent from Samoa and all islands to the east; notable among these are all hawks (of which *Astur* and *Circus* occur in Fiji), and the Woodswallow (*Artamus*). The absence of these from the islands beyond Fiji is in accordance with the general rule that as one passes eastwards some form of animal life is left behind, whenever the sea between two groups of islands is crossed. But among the birds there are at least two anomalous species which are absent from Samoa, but present in islands to the eastwards: *Hirundo tahitica* is known to be found in the Bismarcks, Solomons, New Hebrides and Fiji, and also in the Society Islands; the genus *Conopoderas* (*Tatare*) contains Warblers related to the Reed Warblers. It is absent from Samoa and the whole of Western Polynesia, but in the Marquesas, Austral and Society Islands a number of endemic forms occur (Murphy and Matthews).

The sea birds known to occur in Samoa are probably of little interest to us, though the absence of Cormorants is remarkable.

It will be noticed that the Samoan avifauna is peculiar both in respect of absentees, and of groups represented in it. It is not possible to explain the anomalies, as one is tempted to do in an island so far from continents, by saying that only birds of strong flight can have reached it. This is far from being true, for Samoa possesses fruit doves, a white eye, and other forest birds which are never seen to fly far, and it lacks hawks, crows and swallows.

The Samoan birds are derived from the west, and they have little relation to the specialized avifaunas of the Hawaiian Islands, or of New Zealand, and none at all to that of America. Admitting their derivation from the west, are they to be regarded as Australian or Oriental? The question is, perhaps, rather one of definition than of fact; it is well to remember that prevalent views on the distribution of living things are traceable, to a great extent, to Wallace's "Geographical Distribution of Animals." The regions and sub-regions there defined, in so far as they relate to our problem, were partly delimited by Wallace

during his travels in the Malay Archipelago. He had himself passed from Bali to Lombok, leaving behind him the Finches, Woodpeckers, and many other Asiatic birds, and meeting for the first time the Honeysuckers (Meliphagidae) and other families characteristic of the region which he called Australian. His own vivid recollection of his travels, and the fact that he had to draw most of his conclusions from the study of birds alone, perhaps led Wallace to be unduly emphatic in separating the Australian and Oriental faunas in the tropical islands, which stretch from Malaya to the centre of the Pacific. "Wallace's line" certainly marks the eastern limit of many important groups of animals, and also delimits the westward spread of others. But it is only one of many lines which the naturalist crosses as he goes eastwards from the Malay Peninsula, at each of which some familiar and conspicuous group of animals is left behind. If one pays undue attention to any of these eastward limits, one misses what is essential; for the fauna of Papua is to a considerable extent Asiatic, though many Asiatic forms are absent; the fauna of Melanesia is again largely Asiatic, as is that of Fiji, and of Polynesia, each successive fauna being less complete and more oceanic than that which exists to the west of it.

Coming now to Samoa itself, many of the birds are characteristically "Australian" in Wallace's sense of the word. Even in this limited fauna there are no less than three genera of honeysuckers (*Ptilotis*, *Leptornis* and *Myzomela*); there is also a lory (*Vini*). On the other hand, there are a kingfisher (*Halcyon*), a thrush (*Turdus*), and several genera of pigeons, groups which are at least as Oriental as they are Australian. Similarly, among the absentees are a number of characteristic Australian birds, and others, the crows and the hawks, which are of general distribution. It would, perhaps, be fair to say that the avifauna of Samoa is very limited, and that certain widely spread families are absent; that it has been derived from the west; that its origin is partly from Asia, and partly from Australia.

Of Reptiles, Samoa has four species of sea snake (*Laticauda*, three species; *Pelamis*, one species), but these are not likely to be of zoogeographical interest. There is only one terrestrial snake, a boa (*Engyrus bibroni*), found also in Tonga; no land snake is found to the east of Samoa and Tonga. Ten or eleven lizards are recorded, about equally divided between the Geckonidae and Scincidae. All the lizards have a wide distribution in Oceania, and the range of several extends from the Moluccas to the Paumotu Islands. We do not know the explanation of the wide distribution, but it is certainly clear that no lizards have

reached Samoa except those which possessed the power of extending their distribution remarkably. There are no land tortoises or crocodiles in Samoa. AMPHIBIA are absent, frogs extending eastwards through Melanesia to Fiji, but not into Polynesia.

No genuine fresh-water FISH occur in Samoan streams and swamps. The fish which are abundant in these places are all clearly derivable from the sea; there are, for instance, gobies, and two species of *Kuhlia*, a genus of marine fish, some species of which have entered fresh water. The marine vertebrates and invertebrates of Samoa can probably give no clue to the zoogeographical problems, for in most groups of marine organisms great uniformity prevails through the tropical Pacific, and very many forms are also widely spread in the Indian Ocean.

The PRAWNS, so characteristic of Samoan mountain streams, may perhaps be considered here. Our collection contained representatives of *Palaemon*, *Leander* and *Caridina*. The first two are so nearly related to marine forms that they do not show whether Samoa is or is not oceanic. *Caridina* is a member of the Atyidae; these prawns, as Dr. W. T. Calman tells me, are doubtless a true and ancient fresh-water group. But the genus and some of the actual species are so widely spread, that he is tempted to suppose that they must at times enter the sea. In any case their distribution is anomalous, and does not appear to throw any light on our problem.

It is generally admitted that the terrestrial MOLLUSCA give valuable information about the ancient relations of a fauna. The most general paper on these animals in the Pacific is by Pilsbry. He points out that *Partula* is widely spread in Melanesia and Polynesia, and that it is an ancient generalized type, not found elsewhere. On the other hand, many groups found widely spread in the world (*e.g.* Helicidae and Arionidae) are absent, though members of these groups have been able to colonize oceanic islands in other parts of the world. Throughout Polynesia, and including Hawaiia, the snail fauna is remarkably uniform, though it is so unlike that found in other parts of the globe. From these, and other facts, Pilsbry concludes that there was once a continental mass, including all of Polynesia, with Hawaiia; this continent broke up into smaller land areas in middle Mesozoic times, and the fact that this event took place so early accounts for the absence of mammals and other groups from Polynesia. In my opinion, Pilsbry has been more successful than any other writer in making a case for the former existence of a mid-Pacific continent, but I find it difficult to accept his

view, for it seems to conflict with our general knowledge of the fauna of the area. Moreover Hedley, an authority on Mollusca and on Pacific faunas in general, appears to have reached a conclusion different from Pilsbry's. Hedley points out that the land shell *Placostylus* is large and heavy, and that it is not likely that it has crossed the sea. It is found in all Melanesia, including New Caledonia and the Loyalty Islands ; also in Fiji ; also in New Zealand. But it is not known to occur in Samoa. This observation appears to support the view that Samoa is oceanic, and to conflict with Pilsbry's view, unless, indeed, Pilsbry's continent had already become a number of islands before *Placostylus* reached its present home.

In the forests we commonly found NEMERTEANS. Our specimens have been identified by Miss Hett as *Geonemertes palaënsis*. She reports that they belong to a species previously recorded from the Pelew Islands and Celebes. The material from Samoa shows that the species has an enormous oceanic range, and it seems probable that this may be explained by the fact that the natives made long voyages in canoes, in which they carried great quantities of vegetables (page 28). If this explanation is correct, then *Geonemertes* contributes nothing to zoogeography. For a similar reason one would expect that little could be learnt from earthworms, had a collection been made.

One may, perhaps, summarize our general knowledge of the Samoan fauna (exclusive of the insects, to be discussed later) in the following terms :—

1. The fauna is that characteristic of "Oceanic" islands, in the sense in which the term was used by Darwin and by Wallace ; there are no indigenous land mammals (except bats), no amphibia, no freshwater fish ; many widely distributed animals and groups of animals are absent ; the proportion of endemic species and genera is high ; there are no species of very high antiquity, or very great morphological interest.

2. The fauna is derived from the west, and not from America.

3. The fauna is related to that of Asia and Malaya, at least as much as it is to that of Australia. Wallace's attribution of Polynesia to his "Australian Region" is disputed.

It will be seen that the faunistic evidence is definitely opposed to the view that Samoa is a relic of a former continental mass. Had it been so, it would not have had an "oceanic" fauna, and some relation would have been discovered with the plants and animals of the American continent.

## Flora.

On the coast of the Samoan islands one finds typical strand plants. Some are low herbs, straggling over the sand, others are shrubs and trees: all alike have a very wide range, and many of the species are known both from the Indian and the Pacific Oceans (Plate 4, A). It is probable that all, or nearly all, these plants have reached Samoa as floating seeds (see Guppy, vol. 2; Setchell, p. 18, etc.). It is probable that there is an associated fauna of widely distributed insects, but the point has hardly been investigated. The vegetation of all other parts of Samoa is luxuriant, as the temperature is high and constant, and rain falls abundantly at all seasons. Except where man has made clearings, the islands are covered with a dense general covering of plants, which grow even on the cliffs. As in other tropical rain forests, many sorts of trees grow, mixed with one another and with shrubs, creepers and epiphytes (Plates 1 to 3, 5 and 6). Above about 1,500 feet the island is frequently covered with cloud, so that precipitation is high and evaporation is low; these conditions produce exceptional luxuriance, and the mountain forests contain a great variety of epiphytic ferns, mosses and liverworts. At first sight it was not easy to detect any seasonal changes in the vegetation, which is evergreen, so far as its general effect goes. But one soon found that particular species of plant and tree had definite flowering seasons; for instance, *Erythrina indica* flowered in July, wherever it occurred; many other trees had equally definite seasons, so that the Honeypeckers and Lories would be found congregated at blossom in some particular part of the forest, and the Fruit Doves would be at work on some different species of tree, which had been in flower a couple of months earlier. Setchell suggests that these seasonal events may be due to temperature. This seems to me to be improbable in view of the fact that the latter is nearly constant (page 14). I venture to suggest that a more probable cause is the great difference in solar radiant heat received at different seasons (page 13).

The flowering plants have been studied carefully, particularly on Upolu and Tutuila; over 800 species are known, of which more than 30 per cent. are endemic to Samoa, or to one island in Samoa. The other land plants have been less carefully collected, but 260 species of ferns, etc. (Pteridophytes), 395 mosses and hepatics, 214 fungi and 184 lichens are already known; one is therefore justified in saying that these groups form a high proportion of the total land flora.

The flora of Melanesia and the greater part of Polynesia is derived from the west, and is an extension of that of Malaya ; except perhaps in Easter Island, and along the extreme easterly fringe of Polynesia, there is no relationship with the flora of America ; there is also no relationship with the peculiar flora of New Zealand. In their flora, the islands of Samoa most nearly resemble Fiji and Tonga ; the three appear to form a definite group, not closely like other Polynesian archipelagos. But it is understood that the resemblances even to Fiji and Tonga are not very great. Not only are more than 30 per cent. of the flowering plants of Samoa endemic, but there are striking general peculiarities. Setchell (page 28) mentions the absence of trees of the orders Compositae and Lobelioideae, and the absence of all Pittosporaceae and Gymnosperms. Apart from the endemicity, and the absence of these groups, Setchell calls attention to the fact that many of the prevalent plants have small seeds, which render dispersal by wind possible. Our knowledge of the flora is consistent with the view that Samoa is an oceanic archipelago.

The principal authorities on the flora of Samoa are Rechinger and his associates, Reinecke and Setchell. Setchell's work is the most recent, and his monograph includes a general summary on the vegetation of the group ; he also gives lists of introduced plants and weeds, and devotes very full attention to the plants which are used by the Samoans ; on his work I have based this short account.

## THE PEOPLE.

The geologist has to study the Pacific without the aid of fossils or strata ; the difficulties of the anthropologist are similar, for his subjects have left no relics in flint, earthenware or metal. But it appears to be almost a matter of agreement among anthropologists that the peoples of Melanesia and Polynesia came from the west : they are emigrants from S.E. Asia.* The evidence for this view does not concern us, but it is interesting to discover certain zoological facts which tend to confirm it. It is known that both Melanesians and Polynesians kept domestic swine before the coming of the white man ; the animals were an important part of the food supply, and in parts of Oceania had also a

* The view is held in certain quarters that the civilization of America has been influenced by Asia and by Egypt ; it is interesting to observe that no support to this view can be found in the fauna or flora, or in the useful plants of Polynesia. The cultivated plants of Tropical America, for instance Paw Paw and Manioc, were absent from Samoa until introduced by Europeans.

great value in ritual. These aboriginal pigs no longer exist as a pure stock, for European pigs have been imported at intervals for more than a century. But the connection with Asia is suggested (not proved) by the discovery of the Nematode *Bourgelatia diducta* in the intestines of pigs in Mauke, Cook Islands, and in Tonga ; this worm was previously recorded only from Annam (Schwartz). The lice collected on pigs both in Samoa and the New Hebrides suggest the same conclusion ; they were determined by Waterston as *Haematopinus suis* var. *adventicius*, a variety described by Neumann from wild swine in S.E. Asia. The helminthic parasites of man are much less easily explained. The facts are very well known, owing to the work of Lambert ; he has shown that in Papua, and wherever he has worked in Melanesia and Polynesia, the people are infected by the whipworm (*Trichuris trichuris*) and by *Necator americanus*, a relative of the hook-worm. On the other hand, they do not harbour the round-worm (*Ascaris lumbricoides*), nor the hook-worm (*Ancylostoma duodenale*), except where these parasites have been recently introduced by Asiatic labourers. The evidence relating to human migration and history, which may be derived from *Ancylostoma* and *Necator*, is reviewed by Darling. He shows that *Necator* is characteristic of tropical Africa, and of Papua and Oceania. *Ancylostoma* is prevalent in Europe, N. Africa and Asia. At first sight, then, the evidence to be derived from these two worms appears to conflict with the view that the people of Oceania are Asiatics. But this is not necessarily the case, for the people of South India are mainly infested with *Necator ;* in Java this worm is found in pure culture in remote places in the hills ; in other places, where a part of the native race was derived from India in historic times, the prevalent parasite is *Ancylostoma*. One may, therefore, say that the evidence to be derived from these worms is not inconsistent with the Asiatic origin of the peoples under discussion ; the absence of *Ascaris lumbricoides*, and the fact that when it is introduced it quickly becomes common, are at present unexplained. The complete absence of Cestodes and of *Trichinella spiralis* from a human population intimately associated with pigs and rats is also anomalous.

Let us accept it, then, that the people came out of Asia, travelling eastwards and leaving many plants and animals behind them as they did so. By the time they arrived in Samoa, they had left betel and sago, *Anopheles* and *Plasmodium* far behind them. But they brought with them many cultivated plants, and also dogs, pigs and cats ; I have already mentioned the small rat (page 19), the present distribution of which suggests that it was carried by man. Samoa, so

central though so isolated, became one of their principal centres of dispersal. Indeed, the name Savai'i is equivalent to " Hawaiki," the traditional home of the Maories of New Zealand. Though much of the ancient culture disappeared more than a century ago, enough has been preserved to give us a fair general knowledge of it. The people were seafarers, with a traditional system of navigation ; they put to sea in great canoes, which carried scores of people, and supplies of food for many days ; their commerce and their raids frequently carried them many hundreds of miles across the open ocean. Beyond this small canoes must frequently have been blown away from home, as they are to this day ; these would be carried down wind, that is to say, back towards Asia, so that coming and going was much more general throughout Polynesia than one would have supposed. As I have recently published a number of facts about native voyages (Buxton, 1928, p. 99), no more need be said here, but the fact that these voyages occurred, and that great quantities of food and other materials were transported, must not be forgotten ; the great canoes must have been potent in carrying insects and small animals, also weeds, from one archipelago to another.

The ancient Samoans had many needs, and knew how to meet them ; they were, in fact, civilized. They were far from being naked simple savages, chewing roots and hiding in caves. Though they knew nothing of clay, flint, or metal, they employed vegetable products in a great variety of ways. They built, and they still build, magnificent houses, choosing particular timbers for lightness, others for strength or elasticity, binding them together with fibres and closing the whole with a thick thatch, and matting sides (Plate 4, C). They made and sailed the great canoes to which we have referred. They were enthusiastic gardeners, with a taste for flowers. They feasted on taro (root of *Colocasia*), bread fruit, yams, sweet potatoes, coconuts, and many other fruits, nuts and roots, some of which were indigenous, others brought from overseas ; they had their sweets and sauces, and employed particular sorts of leaf for wrapping the food that was to be put in the oven. They cultivated Kava, from which they made a ceremonial drink. They fished with lines and nets and traps. They had their clothes for work, and for occasions of ceremony ; they adorned themselves with garlands, anklets and necklaces ; they gave much time and study to the compounding and use of unguents, pigments and cosmetics. In these and very many other ways, they made use of the vegetable kingdom. The subject, which is one of great interest, may be followed further in the works of

Powell, Reinecke, Krämer and Setchell. When we remember that many of the useful plants were cultivated and carried about the Pacific in the voyages, we shall realize what opportunities there must have been for the carriage of insects, worms, molluscs, etc., from one archipelago to another. I hope that when the results of our entomological studies are summarized, I may publish lists of some of the insects which apparently owe their distribution to this cause. The best general account of the Samoan people is the work of Krämer.

It is fitting to conclude these remarks with a few words about the penetration of Europeans into Samoa. So far as we know, until the year 1800 Europeans had only paid four short visits to our archipelago, but in the early years of the nineteenth century there were a few white residents, most of whom had run away from ships. In 1830 the first missionary, John Williams, landed for a few days; he left some Tahitian teachers and returned in 1832. His arrival is of interest to us because he travelled very widely, and wherever he went he introduced new domestic animals and cultivated plants; he also hurried forward the introduction of Western ideas and awoke a demand for foreign products. These needs were soon met, and increased, by ships and traders. For various reasons the superficial Europeanization of Samoa proceeded rapidly from 1830 to 1850. In 1850 European Governments became directly interested in Samoa, though it was not until 1899 that the islands were divided between Germany and the United States.

As regards the fauna and flora, the entry of Europe upon the scene has had many different results. A very great variety of exotic flowers and fruits is now grown, though none is important commercially; the surface of the islands is so rough that no organized development of tropical agriculture seems probable; there are considerable areas of turf, which consists mainly of foreign grasses and other plants. Foreign timber and foreign fruit is commonly seen in Apia. Ships containing sheep and cattle have called, times without number, and are probably responsible for the presence of dung-breeding flies, etc. On the other hand, as the people eat imported food and make use of European fabrics, metals, etc., they resort less and less to the forest for the innumerable products which their ancestors used, and the arts of fowling and fishing are rapidly disappearing. The effect of the foreigners upon the Samoan fauna is therefore complex, particularly so in view of the difficulty of deciding whether a particular insect or plant was brought in by the white man, or centuries ago in a Polynesian canoe. Taking it all in all, it appeared to me that the total effect of the intro-

duced plants and animals was very little; the archipelago is almost entirely covered with virgin forest, containing a wealth of native and endemic forms of life.

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## LIST OF TEXT-FIGURES.



## LIST OF PLATES.





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PLATE I.

Gorge near Malololelei, Upolu, at about 1,800 feet above sea-level.

PLATE II.

River running through ravine, about two miles east of Vailima, at about 600 feet above sea-level.

PLATE III.

Waterfall and torrent near Malololelei, Upolu, at about 1,800 feet above sea-level.

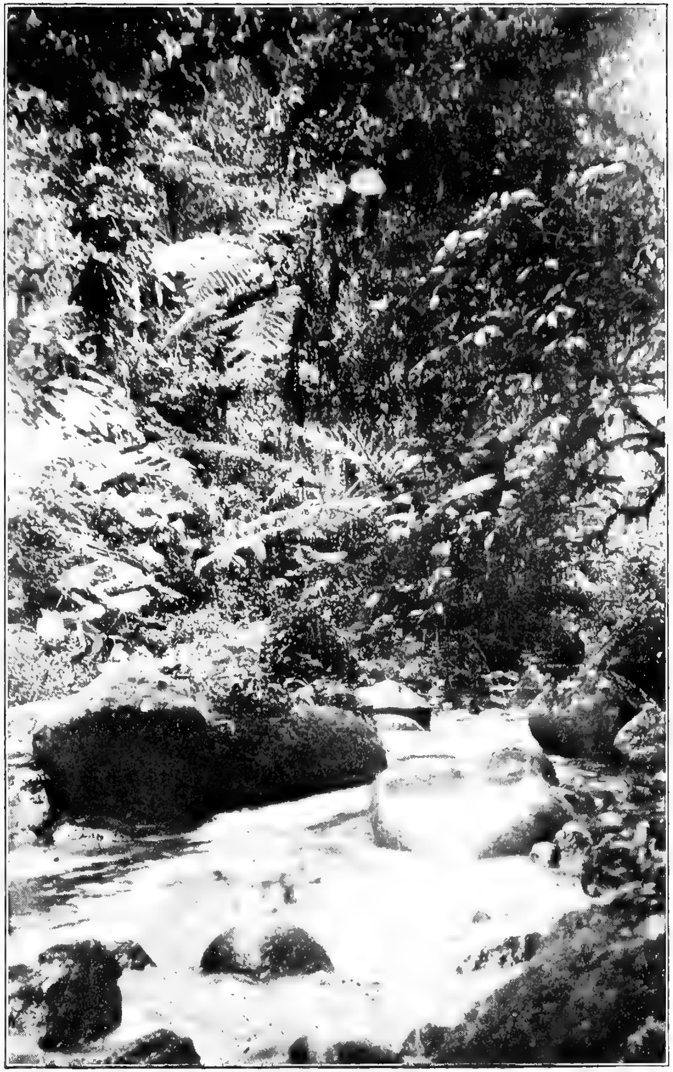
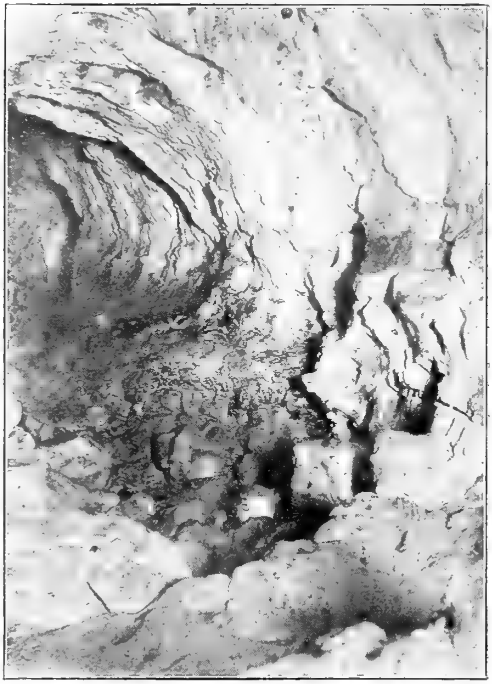


PLATE IV.

*A*. White coral sand, strand vegetation (*Ipomaea*), and coconuts, near Apia. *B*. Lava tunnel, near Malololelei, about 2,000 feet. *C*. Village in Savaii, with breadfruit trees, and turf of foreign grasses and weeds.

*A*



*B*



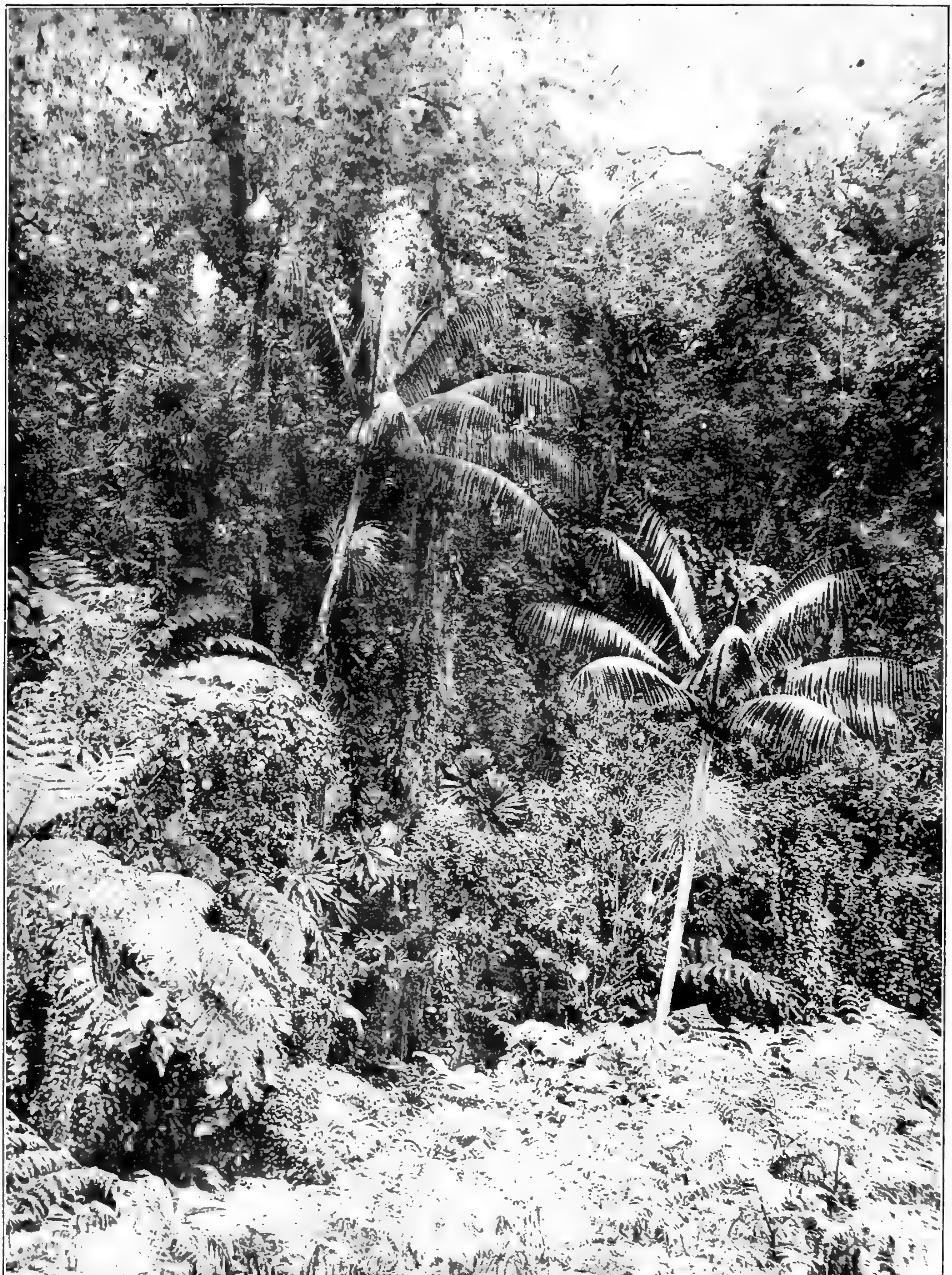
*C*

## PLATE V.

Rain forest near Malololelei, about 1,800 feet.

PLATE VI.

Forest with palms and ferns, near Malololelei, about 1,800 feet.



# INSECTS OF SAMOA
## AND OTHER SAMOAN TERRESTRIAL ARTHROPODA

### LIST OF PARTS AND SYSTEM OF PUBLICATION:—

Part I. Orthoptera and Dermaptera.
,, II. Hemiptera.
,, III. Lepidoptera.
,, IV. Coleoptera.
,, V. Hymenoptera.
,, VI. Diptera.
,, VII. Other Orders of Insects.
,, VIII. Terrestrial Arthropoda other than Insects.
,, IX. Summary and Index.

The work is published at intervals in the form of numbered fascicles. Although individual fascicles may contain contributions by more than one author, each fascicle is so arranged as to form an integral portion of one or other of the Parts specified above.

List of Fascicles issued to 22nd November, 1930:—

| | *Date Issued.* |
|---|---|
| Insects of Samoa and other Samoan Terrestrial Arthropoda. Maps 1 and 2 (in envelope). 1927, 4to. 6*d*. | 26*th February*, 1927. |
| **Part I. Orthoptera and Dermaptera.** | |
| Fasc. 1. Dermaptera. By Dr. Alfredo Borelli. Pp. 1-8. 1928, 4to. 1*s*. | 28*th July*, 1928. |
| Fasc. 2. Orthoptera. By Dr. L. Chopard. 51 text-figures. Pp. 9-58. 1929, 4to. 5*s*. | 26*th January*, 1929. |
| **Part II. Hemiptera.** | |
| Fasc. 1. Fulgoroidea. By F. Muir. 25 text-figures. Psyllidæ (Chermidæ). By Prof. D. L. Crawford. 4 text-figures. Coccidæ, Aphididæ and Aleyrodidæ. By F. Laing, M.A., B.Sc. 3 text-figures. Pp. 1–45. 1927, 4to. 2*s*. 6*d*. | 25*th June*, 1927. |
| Fasc. 2. Cercopidæ. By V. Lallemand, M.D. 10 text-figures. Cicadidæ. By J. G. Myers, Sc.D. 22 text-figures. Aquatic and Semi-aquatic Heteroptera. By Prof. Teiso Esaki. 6 text-figures. Pp. 47–80. 1928. 4to. 2*s*. 6*d*. | 23*rd June*, 1928. |
| Fasc. 3. Heteroptera. By W. E. China, B.A. (Cantab.). 28 text-figures. Pp. 81–162. 1930, 4to. 5*s*. | 26*th July*, 1930. |
| **Part III. Lepidoptera.** | |
| Fasc. 1. Butterflies of Samoa and some neighbouring Island-groups. By G. H. E. Hopkins, M.A., F.E.S. 1 text-figure and 4 plates. Pp. 1–64. 1927, 4to. 5*s*. | 9*th April*, 1927. |
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## List of Fascicles issued to 22nd November, 1930 (*continued*) :—

### PART IV. COLEOPTERA.

| | *Date Issued.* |
|---|---|
| Fasc. 1. Carabidæ. By H. E. Andrewes. 9 text-figures. Dytiscidæ. By A. Zimmermann. 2 text-figures. Staphylinidæ. By M. Cameron, M.B. 2 text-figures. Hydrophilidæ. By A. d'Orchymont. 1 text-figure Clavicornia and Lamellicornia. By G. J. Arrow. 13 text-figures. Pp. 1–66. 1927, 4to. 3*s.* | 19*th December*, 1927. |
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| Fasc. 3. Throscidæ. By K. G. Blair, B.Sc. 1 text-figure. Chrysomelidæ. By S. Maulik, M.A. 18 text-figures. Pp. 175–215. 1929, 4to. 2*s.* 6*d.* | 23*rd February*, 1929. |
| Fasc. 4. Platypodidae and Scolytidae. By C. F. C. Beeson, D.Sc. 13 text-figures. Pp. 217–248. 1929, 4to. 2*s.* 6*d.* | 22*nd June*, 1929. |

### PART V. HYMENOPTERA.

| | |
|---|---|
| Fasc. 1. Apoidea, Sphecoidea, and Vespoidea. By R. C. L. Perkins, D.Sc., F.R.S., and L. Evelyn Cheesman, F.E.S., F.Z.S. 12 text-figures. Larridæ. By Francis X. Williams. 12 text-figures. Formicidæ. By Dr. F. Santschi. 9 text-figures. Pp. 1–58. 1928, 4to. 5*s.* | 25*th February*, 1928. |

### PART VI. DIPTERA.

| | |
|---|---|
| Fasc. 1. Streblidæ and Nycteribiidæ. By L. Falcoz. 7 text-figures. Hippoboscidæ. By G. F. Ferris. 6 text-figures. Pp. 1–21. 1927, 4to. 2*s.* 6*d.* | 23*rd July*, 1927. |
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| Fasc. 3. Stratiomyiidæ, Tabanidæ and Asilidæ. By Gertrude Ricardo. 6 text-figures. Larvæ of Stratiomyiidæ. By P. A. Buxton, M.A. 2 text-figures. Dolichopodidæ. By C. G. Lamb, Sc.D. 8 text-figures. Sarcophagidæ. By P. A. Buxton, M.A. 9 text-figures. Muscidæ. By J. R. Malloch. Pp. 109–175. 1929, 4to. 5*s.* | 11*th May*, 1929. |
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| Fasc. 5. Ortalidae. By J. R. Malloch. 6 text-figures. Calliphoridae. By J. R. Malloch. Pp. 215–237. 1930, 4to. 2*s.* | 22*nd March*, 1930. |
| Fasc. 6. Lonchaeidae, Chloropidae and Piophilidae. By J. R. Malloch. 3 text-figures. Pp. 239–251. 1930, 4to. 1*s.* | 22*nd November*, 1930. |

### PART VII. OTHER ORDERS OF INSECTS.

| | |
|---|---|
| Fasc. 1. Isoptera : Family Termitidæ. By Gerald F. Hill. 14 text-figures and 1 plate. Odonata. By Lt.-Col. F. C. Fraser, I.M.S., F.E.S. 5 text-figures. Pp. 1–44. 1927, 4to. 2*s.* 6*d.* | 28*th May*, 1927. |
| Fasc. 2. Plectoptera. By R. J. Tillyard, Sc.D. (Cantab.), F.R.S., and J. A. Lestage. 2 text-figures. Siphonaptera. By P. A. Buxton, M.A. Thysanoptera. By Richard S. Bagnall, F.R.S.E., F.L.S. 6 text-figures. Pp. 45–76. 1928, 4to. 2*s.* 6*d.* | 23*rd June*, 1928. |
| Fasc. 3. Mallophaga. By J. Waterston, D.Sc. 2 text-figures. Anoplura. By P. A. Buxton, M.A. Trichoptera. By Martin E. Mosely. 1 figure. Neuroptera. By P. Esben-Petersen. 1 text-figure and 2 plates. Apterygota. By George H. Carpenter, D.Sc. 32 text-figures. Pp. 77–116. 1928, 4to. 2*s.* 6*d.* | 28*th July*, 1928. |

### PART VIII. TERRESTRIAL ARTHROPODA OTHER THAN INSECTS.

| | |
|---|---|
| Fasc. 1. Isopoda Terrestria. By Harold G. Jackson, D.Sc. 2 plates. Scorpionoidea. By P. A. Buxton, M.A. Pseudo-scorpiones. By A. Kästner. 11 text-figures. Acarina. By Stanley Hirst. 2 text-figures. Pp. 1–27. 1927, 4to. 2*s.* 6*d.* | 23*rd July*, 1927. |
| Fasc. 2. Myriopoden (Myriopoda). By C. Attems. 4 text-figures. Araignées (Araneida). By Dr. Lucien Berland. 79 text-figures. Pp. 29-78. 1929, 4to. 2*s.* 6*d.* | 22*nd June*, 1929. |

### PART IX. SUMMARY AND INDEX.

| | |
|---|---|
| Fasc. 1. Description of the Environment. By P. A. Buxton, M.R.C.S. 2 text-figures and 6 plates. Pp. 1–31. 1930, 4to. 2*s.* 6*d.* | 22*nd November*, 1930. |